CONSERVATION AGRICULTURE AND CLIMATE CHANGE

IMPACTS AND ADAPTATIONS

Editors

RITESH SAHA DHANANJAY BARMAN

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Conservation Agriculture and Climate Change Impacts and Adaptations

A Unit of
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About the Editors

Dr. Ritesh Saha, born on 15th January 1974 in Kolkata West Bengal, is presently working as Principal Scientist in the Division of Crop Production, ICAR-CRIJAF, Barrackpore, Kolkata. He started his professional career as Scientist (ARS) in 1999 and served at various research institutes like ICAR-CIFRI, Vadodara centre; ICAR Research complex for NEH Region, Meghalaya; ICAR-IIHR, Bhubaneswar Centre and ICAR-IISS, Bhopal. He is a Soil Scientist with Specialization in Soil Physics and Soil Water Conservation. He has 22 years of experience in research and training in the field of soil physics, soil quality and physical health, rainwater harvesting, water conservation, land configuration and conservation agriculture. Notable contributions of Dr. Saha include integrated assessment of zero tillage and organic residue management on soil physical behaviour, water productivity and sustainability under rice and jute based cropping system, analysis of carbon stock density under long-term experiment/field trials in various agro-ecosystem; Development of farming system approach with special intervention of agroforestry for maintaining soil quality against the traditional land use practice of shifting cultivation; Identification of perennial grasses based on hydro-physical behaviour and organic carbon dynamics for improving soil quality in degraded land; Development and standardization a new method of low-cost micro rainwater harvesting technology (Jalkund) for enabling diversified use of stored water for various farm activities like crop, livestock and fish production during water-stress period under hilly terrain; and Evaluation of raised and sunken bed system (RSB) for increasing water economy and total system productivity under rice-based cropping system.

Dr. Saha has to his credit more than 70 research papers published in journals of international and national repute. Besides this, he also authored 3 books, 25 book chapters, 11 research bulletins, 5 extension leaflets, 10 technical articles, 11 review articles and 7 popular articles. He has also presented over more than 60 research papers in both national and international conference. His outstanding work done in the field of scientific research with special emphasis on soil quality/resilience, rainwater harvesting, conservation agriculture, C sequestration has brought many laurels/prestigious awards like Golden Jubilee Commemoration Young Scientist Award of Indian Society of Soil Science, New Delhi (2012), Associate Fellowship from National Academy of Agricultural Sciences (2014) and Dr B C Deb memorial award for popularization of science by Indian Science Congress Association, Kolkata (2015), SURE Scientist of the Year award by Society for Upliftment of Rural Economy, Varanasi (2014), BIOVED Young Scientist Associate award (2016), and Dr. J S P Yadav Memorial Award for Excellence in Soil Science (Team award) by, ISSS, New Delhi (2016).

Dr. Dhananjay Barman, born on 7th May 1982 in Dinhata, Cooch Behar district, West Bengal, is presently working as Senior Scientist in the Division of Crop Production, ICAR-CRIJAF, Barrackpore, Kolkata. He started his professional career as Scientist (ARS) in 2008 at ICAR-IISWC, Research Centre, Koraput, Odisha. He is a Soil Scientist with Specialization in Remote Sensing, GIS and Soil Physics.

He has 13 years of experience in research and training in the field of Agro-climatology, Remote Sensing and GIS, Soil Physics, Soil and Water Conservation, Watershed Management and Agroadvisory Services. Notable contributions of Dr. Barman include his development of JuteMet®, a web-based Agrometeorological Database Management System (ADBMS)-cum-Agroadvisory System, and obtained Trademark for that. He also developed models for soil temperature prediction from air temperatures in Indo-Gangetic plain. He has experience in eddy covariance technique and using this technique he measured CO_2 sequestration potential of jute-based agroecosystem. He successfully used GIS and remote sensing-based approach for mapping of potential areas for mango-sisal intercropping system in red and laterite zone of West Bengal, and land use/ land cover dynamics of shifting cultivated areas in Eastern Ghats Highlands of India. Dr. Barman has to his credit 35 research papers published in national and international journals. He also authored 8 book chapters, 3 research bulletins, and many technical articles.

Dr. Barman has been bestowed with Young Scientist Award (2016) in NRM, and Outstanding Scientist Award (2019) in Agricultural Physics conferred by Venus International Foundation; Young Scientist Award (2019) conferred by Indian Association of Soil and Water Conservationists, Dehradun; and Best Young Scientist Award (2021) conferred by ICAR-CRIJAF, Barrackpore.

Dr. Madhusudan Behera was born in Keonjhar district of Odisha in 1961. He obtained his Ph.D degree from Odisha University of Agriculture and Technology in 2009. Dr. Behera started his professional experience as a Research Associate followed by Junior Agronomist at OUAT, Bhubaneswar and served various Institutes like Rubber Research Institute of India, Kottayam as Junior Scientist and ICAR-Indian Institute of Water Management, Bhubaneswar as Chief Technical Officer. He is presently working as Principal Scientist (Agronomy) in Division of Crop Production at Central Research Institute for Jute and Allied Fibre Barrackpore with specialization in Agronomy.

He has 33 years of experience and implemented 32 nos of Multi-disciplinary projects as PI and Co-PI in the field of Integrated Farming System, Cropping Systems, Crop Diversification, Micro-irrigation, Integrated Nutrient Management, Conservation Agriculture Practices, Organic farming, and Watershed management.

To disseminate these technologies in farmers field, he has organized and delivered lectures at Farmers Trainings, Trainer's Trainee Programmes, Farmers Fair, Field Day, Front Line Demonstrations under SCSP, NEH, TSP, Jute ICARE, Govt. Of India, ICAR, SWPA, FPARP, SAU, NATP, NABARD including radio talks, articles in newspaper and publication of more than 100 book chapters, research bulletins, leaflets and folders and Training Manuals. Based on the outcomes of the projects, he has 39 nos of publications in various national and international journals along with 65 nos of abstracts in different national and international conferences and seminar. He is also involved in reviewing various research papers for National and International Journals. He is associated with affiliated Professional Societies and bodies as active member. His research papers were acknowledged at various platforms and forums and awarding papers with Dr. JSP Yadav Best paper Award, Krishi Gaurav Samman, Best Paper Award, Best Poster Awards at various Conferences and Institutional Proficiency Awards for his services towards the Institution. Moreover, Dr Behera is the receiver of the prestigious Bharat Jyoti Award for his meritorious service, outstanding performance and remarkable contribution in his field in the year 2014.

Dr. Gouranga Kar, born on 1st September, 1968 in Bankura, West Bengal, is presently the Director of ICAR-Central Research Institute for Jute & Allied Fibres (CRIJAF), Barrackpore, Kolkata. He did his M.Sc and Ph.D in the discipline of Agricultural Physics in 1993 and 1996, respectively, from Indian Agricultural Research Institute (IARI), New Delhi. He started his professional career as Scientist (ARS) in Aug., 1996 at ICAR-Indian Institute of Water Management (IIWM), Bhubaneswar, Odisha and served there at various capacities till 2020.

He has 25 years of research experience in the field of Land use and cropping system characterization using remote sensing and GIS, crop growth modelling, water and watershed management, climate change research, mitigation and adaptation strategies. He has handled many externally funded projects as Principal investigator during his stay at Bhubaneswar. Some of the important projects are National Innovation for Climate Resilient Agriculture (NICRA) funded by Ministry of Agriculture and Farmers' Welfare, GoI; Integrated watershed management project (IWMP) sponsored by Odisha Watershed Development Mission, Bhubaneswar; Farmers' Participatory Action Research Programme (2nd Phase) funded by Ministry of Water Resources, GoI; Natural resource mapping and hydrologic study of watershed using remote sensing and GIS sponsored by DST, GoI and Developing low cost technology for acid soil management funded by TIFAC, GoI. For pursuing the frontier research, he was awarded with Norman Borlouge Fellowship in 2008 and Fulbright-Nehru Senior Research Fellowship, USA during 2011-12. His research work has been published in different leading international and national journals with high repute. He contributed more than 300 publications which includes referred journals, reviews, book/book chapters, research bulletin, training manual/leaflets, proceedings of seminar/conferences etc.

Dr. Kar is recipient of several national and international awards/honours, namely, ICAR-Hari Om Ashram Trust Award (2008), ICAR-Vasant Rao Naik Award (2005), Rajbhasa Gaurav Puraskar, Ministry of Home Affairs, GoI (2019, NAAS Recognition Award (2012), ICAR-Swami Sahajananda Saraswati Award (2019), Fulbright-Nehru Senior Research Fellowship, USA (2011-12), IARI-Hooker Award (2018), IARI-Sukumar Bose Memorial Award (2007), Dr K.G. Tejwani Award of IASWC (2008), Associates of NAAS (2008), Young Scientist Award of Indian Science Congress Association, ISCA (2001), Young Scientist Golden Jubillee Commemoration Award of ISSS (2006), Ekamra Shree Award of Govt of Odisha (2016), Rajdhani Gaurav Samman of Govt of Odisha (2015), Ekamra Shree Award of Govt of Odisha (2017). He is fellow of National Academy of Agricultural Sciences; FNAAS (2011), Indian Association of Soil & Water Conservationists; FIASWC (2012), Association of Agrometeorologists; FAAM (2010), Indian Society of Soil Science; FISSS (2018), West Bengal Academy of Science and Technology; FWAST (2017) and Indian Society of Coastal Agricultural Research; FISCAR (2020).

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Foreword

There is global consensus that current climate is changing and it is for real. Agriculture is one sector of the economy that is exposed directly and considerably affected by climate change and climate variability. Rural communities are struggling with the realities, together with declining farm productivity and rising cost of cultivation associated with depleting and degrading natural resources. Climate resilient agriculture therefore requires a major shift in the way land and water are managed to ensure that these resources are used more efficiently.

Conservation agriculture (CA) is a farming system approach that promotes minimum soil disturbance (some people loosely call it as ‘no' tillage) together with maintenance of a permanent soil cover, and diversification of plant species reinforcing ecosystem services through a number of interrelated pathways. The production of food in CA reinforces the ecosystem services through nutrient recycling, soil formation habitat derived from crop rotation, minimum soil disturbance together with plant residue retention, have also the minimal impact on climate change. Despite some challenges associated with CA, if implemented judiciously, CA could ensure current food security and nutrition for all without compromising the economic, social, and environmental bases for future generations. There is a need to sensitize the resource poor farmers/stakeholders about CA through innovative participatory approaches.

This book entitled "Conservation Agriculture and Climate Change: Impacts and Adaptations" will provide a comprehensive understanding of the subject with topics related to climate change mitigation strategies, approaches and impact of conservation agriculture on natural resource management. I hope this book will be useful to researchers, teachers and students to understand CA as climate smart agricultural practice for sustainable agriculture in present day scenario.

I congratulate Dr. Ritesh Saha, Principal Scientist (ICAR-CRIJAF) and other Editors for publishing this book in academic spirit.

H Sen.

Dated the 22nd April, 2021 (H.S. Sen)
Kolkata

Preface

Conventional tillage and burning crop residues has degraded the soil resource base and intensified soil degradation with concomitant decrease in crop production capacity. The emerging issue of global warming coupled with green house gases emissions has further aggravated the scenario. Conservation agriculture (CA) helps in reducing many negative effects of conventional agriculture such as soil erosion, soil organic matter (SOM) decline, water loss, soil physical degradation, and fuel use. CA helps to improve biodiversity in the natural and agro-ecosystems. Complemented by other good agricultural practices (GAPs) including the use of quality seeds, integrated pest, nutrient and water management etc., CA provides a base for sustainable intensification of the agricultural production system. Moreover, the yield levels in CA systems are comparable and even higher than traditional intensive tillage systems with substantially less production costs.

The conservation agriculture (CA) practiced over an estimated 100 M ha area worldwide and across a variety of climatic, soil and geographic zones, has proved to be energy and input efficient, besides addressing the emerging environment and soil health problems. The CA technologies involving no- or minimum tillage with direct seeding and bed planting, residue management (mainly residue retention) and crop diversification have potential for improving productivity and soil quality, mainly by soil organic matter (SOM) build-up. This bring many possible benefits including reduced water and energy use (fossil fuels and electricity), reduced greenhouse gas (GHG) emissions, soil erosion and degradation of the natural resource base, increased yields and farm incomes, and reduced labor shortages.

We place on record our sincere thanks to all the authors for their support and contribution. We wish to express our deep sense of gratitude to Dr. T. Mahapatra, DG (ICAR) and Secretary (DARE) for his constant encouragement to us. We profusely thank Education Division, Indian Council of Agricultural Research, New Delhi for sponsoring the Short Course training on "Recent advances in Resource Conservation Technologies (RCTs) under Aberrant climate Change Scenario". We are also thankful to M/s New India Publishing Agency, New Delhi for their support in compilation, designing and publishing the book.

We do hope, this book will be of immense use to researchers, scientists, students and policy makers for efficient and sustainable management of natural resources under climate change scenario.

Dated the 15th April, 2021 **Editors**

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Conservation Agriculture Approaches for Reducing Carbon Footprints

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Introduction

Intensive soil tillage, burning of crop residues and over use of fertilizer and irrigation water under current agricultural practices has accelerated the pace of degradation in Indian agriculture. Intensive soil tillage increases soil erosion and nutrient runoff into nearby waterways. Crop residue burning resulting in loss of plant nutrients and release of greenhouse gases (GHGs) in the atmosphere. Imbalanced use of chemical fertilizer leads to soil compaction, slows down the fertilizer utilization rate and contaminates the local environment. Increasing demand of irrigation water causes water shortage and harms the environment in several ways including increased salinity, nutrient pollution, and the degradation of flood plains and wetlands. In the face of these management and environmental challenges, there is a need to formulate such agricultural practices which improve the productivity of natural resources as well as of external inputs and help to prevent soil degradation. Conservation agriculture (CA) practices such as reduced tillage, residue retention and proper crop rotations offer such solutions. CA also helps in making agricultural systems more resilient to climate change and safeguard ecosystem services.

Five key farming strategies that are proven to be effective in increasing crop production while lowering carbon footprint are as follows:

(i) use of reduced tillage in combination with crop residue retention and decomposition to increase soil organic carbon;

(ii) reduction in use of inorganic fertilizer and improvement of nitrogen (N) fertilizer use efficiency including N_2- fixing pulses in rotations to lower the carbon footprints of field crops as N fertilizer contribute about 35 to 50% of the total emissions;

(iii) use of diversified cropping systems and adopting intensified rotation with reduced summer fallow for lowering the carbon footprint by as much as 150 %;

(iv) integration of key cropping practices which can increase crop yield (15 to 60 %), reduce emissions (25 to 50 %), and lower the carbon footprint of cereal crops (25 to 35 %), and

(v) enhancing soil carbon sequestration as the emissions from crop inputs can be partly offset by carbon conversion from atmospheric CO_2 into plant biomass and ultimately sequestered into the soil.

With the adoption of these improved conservation agriculture technology, one can optimize the system performance while reducing the carbon footprint of crop cultivation.

Carbon Footprints from Farm Inputs and Farm Operations

Carbon footprint is a measure of the total emission of greenhouse gases in carbon equivalents (CO_2- Carbon dioxide, CH_4- methane and N_2O- nitrous oxide) from a product across its life cycle from the production of raw material used in its manufacture, to disposal of the finished product (Carbon Trust, 2007). The magnitude of decline or enhancement of carbon due to continuous cultivation depends on the balance between the loss of carbon by oxidative forces and the quantity and quality of crop. The loss of carbon is maximum in tropical and subtropical regions because of high atmospheric temperature (Jenny and Raychaudhuri, 1960). Scientific evidence suggests that 50 to 66 per cent of the cumulative historic carbon loss from soil can be recovered if managed intelligently (Lal, 2004; Velayutham *et al*., 2000).

GHG emissions from field crop production are mostly derived from (1) crop residue decomposition; (2) inorganic fertilizers applied to the crop; (3) various farming operations such as tillage operations, fossil fuels for running of tractors, electricity for running of water pumps, spraying pesticides, planting and harvesting the crop; (4) soil carbon gains or losses from various cropping systems; and (5) emissions of N_2O from summer fallow areas. Below are more detailed descriptions for the major emission contributing factors (Fig. 1).

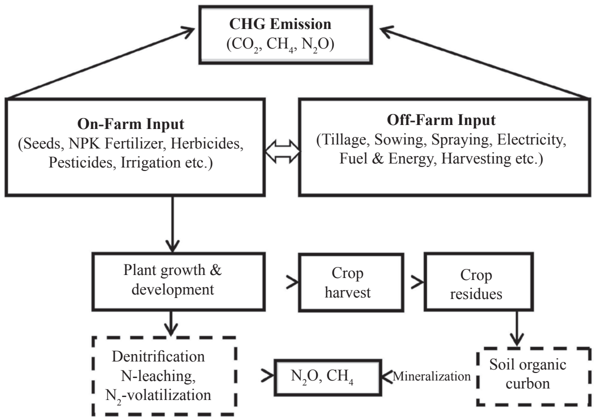

Fig. 1: Greenhouse gas emission during crop production

GHG emission represent per unit of the land used in crop production, per unit weight of the produced yield and per unit of the energy input or output (Soltani *et al*., 2013). The amount of CO_2 produced is calculated by multiplying the input application rate per hectare (e.g. labour, diesel fuels, chemical fertilizers, herbicides and pesticides) by its corresponding coefficient as given in Table 1.

Table 1: Greenhouse gas (GHG) emission coefficient of inputs

Input	Unit	GHG Coefficient (kg CO_2 eq ha^{-1})	Data Source/ Reference
Mouldboard ploughing	MJ	15.2	Singh *et al*. (1999)
Field Cultivation	MJ	4.0	Pathak and Wassmann (2007)
Seed sowing	MJ	3.20	Pathak and Wassmann (2007)
Machinery	MJ	0.071	Dyer and Desjardins (2006)
Diesel fuel	L	2.76	Dyer and Desjardins (2003)
Manure	kg	0.0032	Pathak and Wassmann (2007)
Nitrogen (N) fertilizer	kg	1.30	Lal (2004a); Pathak and Wassmann, (2007)
Phosphorus (P_2O_5) fertilizer	kg	0.20	Lal (2004a); Pathak and Wassmann, (2007)
Potassium (K_2O) fertilizer	kg	0.20	Lal (2004a); Pathak and Wassmann, (2007)
Herbicide	kg	6.30	Lal (2004a); Pathak and Wassmann, (2007)
Insecticide	kg	5.10	Lal (2004a); Pathak and Wassmann, (2007)
Fungicide	kg	3.90	Lal (2004a); Pathak and Wassmann, (2007)
Water for irrigation	mm	0.05	Pathak and Wassmann, (2007)
Harvesting	MJ	10	Pathak and Wassmann, (2007)
Retting	tonne	434	Banik *et al*. (1993)

Source: Singh *et al*. (2018)

Synthesis of the research data as published by Lal (2004a) shows that estimate of GHG emissions (kg CO_2-eq/ha) for different fertilizer nutrients are 0.9–1.8 for N, 0.1–0.3 for P_2O_5, 0.1–0.2 for K_2O, 0.03–0.23 for lime, 6.3 for herbicides, 5.1 for insecticides and 3.9 for fungicides. Similarly, estimates of C emissions are 1–1.4 for spraying chemicals, 2–4 for seed sowing and 6–12 for harvesting. Irrigation, lifting water from deep wells and using sprinkling systems, emits 129 kg CO_2-eq for applying 25 cm of water and 258 kg CO_2-eq for 50 cm of water. Emission for different tillage methods are 35.3 kg CO_2-eq/ha for conventional tillage, 7.9 kg CO_2-eq/ha for minimum tillage, and 5.8 kg CO_2-eq/ha for no-tillage method. A careful assessment is needed to reduce their use, and to enhance use efficiency of these practices.

Farm Practices Reducing Carbon Footprint

Managing tillage practices

A soil disturbance due to tillage is the dominant factor reducing soil carbon stabilization within micro-aggregates in the soil. Carbon emissions depend on numerous factors like soil properties, tractor size, implement used, depth of tillage and quantity of fuel used. The fuel requirement increases with increase in depth of ploughing, tractor speed and type of equipment used for ploughing. The direct fuel consumption is more for heavy than light textured soils (Collins *et al*., 1976). As per study (Lal, 2004a), the average C emission is about 15.2 kg CO_2-eq/ha for mouldboard ploughing, 11.3 kg CO_2-eq/ha for sub-soiling, 8.3 kg CO_2-eq/ha for heavy disking, 7.9 kg CO_2-eq/ha for chiselling, 5.8 kg CO_2-eq/ha for standard disking, 4.0 kg CO_2-eq/ha for cultivator and 2.0 kg CO_2-eq/ha for rotary hoeing. Therefore, conversion of conventional tillage (based on mouldboard ploughing) to reduced tillage (disking or chisel till) can lead to drastic reductions in C emissions. Carbon emission in complete tillage (involving ploughing, two disking, field cultivator and rotary hoeing) is 35.3 kg CO_2-eq/ha that can be reduced to 20.1 kg CO_2-eq/ha by elimination of mouldboard ploughing, and merely 7.9 kg CO_2-eq/ha if follow seeding after chiselling. Reduced tillage in combination with additional carbon input from cover crops can significantly improve the soil organic carbon content (Garcia-Franco *et al*., 2015; Pinheiro *et al*., 2015). Tillage may influence soil carbon and microbial biomass, but may not necessarily increase soil available nutrients or crop yields (Campbell *et al*., 2011).

Crop residues retention and decomposition

Crop residues are normally left on the soil surface or are incorporated into the soil after a field crop is harvested. The crop residues serve as an important C and N source in the soil, contributing directly and indirectly CO_2 and N_2O emissions (Forster *et al*., 2007). The amount of CO_2 and N_2O emission from the decomposition of the straw, stubble, leaves and roots depends on the net productivity of the crop. In a study (Singh *et al*., 2019), the C-input addition through mixing of root-stubble and leaves, under jute-rice-wheat crop cycle helped in doubling the C-input (5.65 t ha^{-1}). Jute plant contributed maximum C inputs (3.80 t ha^{-1}) through retention of root-stubbles and its shredded leaves (Table 2). These large amounts of required C-input to maintain soil organic carbon resulted from net primary production from original biomass production. In the production of economic crops, the carbon footprint can be reduced by effective management of straw, stubble, leaves and roots.

Table 2: Carbon derived from crop residues.

Crop	C-Input addition (t ha^{-1})		
	Root + stubbles	Other residue (leaves)	All residues
Jute	0.97	2.85	3.80
Rice	0.94	-	0.94
Wheat	0.89	-	0.89
Total	2.80	2.85	5.65

Source: Singh *et al*. (2019)

Field experiments on a rice–wheat cropping system in India showed that incorporation of crop residues as compared to burning or removal increased organic carbon contents (Table 3). Soil texture and soil pH play an important role in decomposition of crop residue. Decomposition is more rapid in soils with less clay content. As clay content increases, soil surface area also increases which results in increased organic C stabilization potential (Ladd *et al.,* 1996). In general, decomposition of crop residues proceeds more rapidly in neutral pH soil than in acidic soils. Application of lime in acid soils enhances the decomposition of plant residues (Condron *et al.,* 1993). Alkaline and saline soil also decreased the decomposition of plant residues (Nelson *et al.,* 1996).

Table 3: Effect of crop residue management on organic carbon in soil

Cropping system	Type of crop residues	Soil	Organic C (%)	Reference
Rice-wheat	Rice and wheat straw	Clay loam	0.86	Dhiman *et al*. (2000)
		Silty clay loam	1.24	Verma and Bhagat (1992)
		Sandy loam	0.50	Singh *et al*. (2005)
Rice-mustard	Rice and mustard straw	Sandy clay loam	0.61	Kumar *et al*. (2000)
Rice-rice	Rice straw	Clayey	1.90	IRRI (1986)

Fertilizing crops based on soil tests and including N_2- fixing pulses

More fertilizer doesn't always mean a higher crop production, if there isn't the right mix of nutrients, water and soil health conditions. Soil Health Card (SHC) assessment provide soil nutrient status of each farm and advise corrective dosage of major fertilizers, micronutrient and soil amendments to maintain soil health and obtain a better yield (Singh *et al*., 2020). Imbalanced use of N, P and K leads to the loss of fertility of the soil over a period of time, which affects efficiency of fertilizer use and crop productivity (Rahman *et al*., 2012). The problem is more severe in intensively cropped regions where farmers use excessive nitrogen fertilizer to attain yield levels harvested earlier with less fertilizer (Dwivedi, 2017). Excessive use of fertilizer can also harm the environment and human health through emissions of GHG (CH_4, N_2O, CO_2) and eutrophication caused by the deposits of nitrate and phosphorus in water resources (Bumb and Baanante, 1996). Hence, overall impact and mitigation potential of fertilizer management with regard to GHG emission is important (Singh *et al*., 2018).

Nitrogen fertilizer is the main contributor to greenhouse gas (GHG) emissions especially in cereal production. The average 100% carbon footprint using N fertilizer is up to 3.0 kg CO_2-eq per kg of N (FE, 2014). Increased use of N fertilizer application to the crops increases the total GHG emission. The carbon footprint is a linear function of the rate of N fertilizer applied to the crops, and slope of the linear regression varied with crop species and amount of N fertilizer applied. The decreased use of N fertilization lowers the carbon footprint accordingly. Optimizing N-fertilizer efficiency is key to reduce the GHG emission significantly, depending on soil and weather conditions. A good soil structure increases N-use efficiency and reduces N_2O losses.

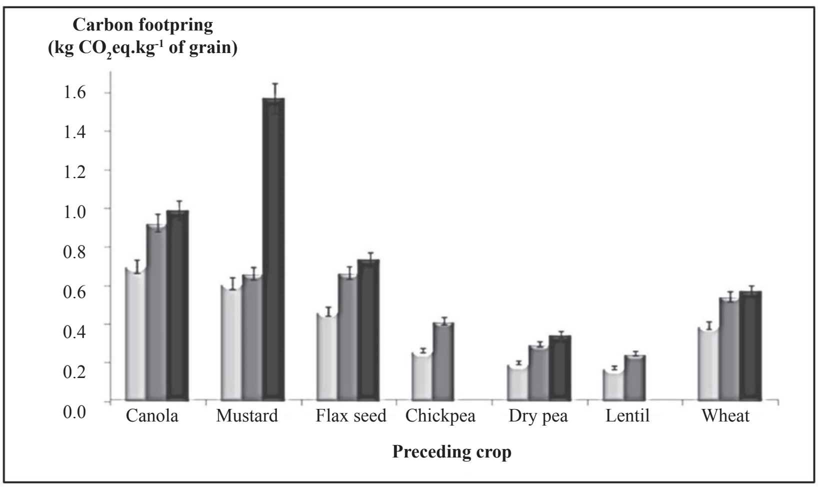

Fig. 2: The carbon footprint in wheat after cultivation of different preceding pulse and non-pulse crop in the crop rotation

Source: Gan *et al*. (2011)

Inclusion of N_2-fixing pulse crops in a crop rotation can significantly decrease GHG emissions and the carbon footprint of the crop grown in the subsequent year (Fig. 2). Symbiotic N_2 fixation by the leguminous crop from the atmosphere significantly decreases the use of synthetic N fertilizer, thus lowering the carbon footprint (Gan *et al*., 2011).

Enhancing water productivity

In the agricultural production systems, maximum energy is utilized in tillage and irrigation management. Efficient water management is one of the potential options for saving and utilizing energy for productive purposes (Choudhary *et al*., 2017). Increasing use of groundwater for irrigation is linked to high energy demand, depleting resources and resulting in a high carbon footprint. Overall water application efficiency for different crops in India is in the range of 40–60% (Grant Thornton, 2016). More than 50% of irrigation water remains unused by the crop and returns to the hydrologic system, either as deep percolation or non-productive evaporation. Hence, reducing water delivery to farms and increasing water use efficiency are important to reduce energy consumption and improving water productivity. Using improved on-farm practices help in reducing the need of irrigation water which in turn results in decreased energy consumption and carbon footprint. Adopting the improved schedule at 65 to 75% efficiency, close to irrigation efficiency in the farm will reduce the irrigation water demand and thereby carbon footprint up to 30% (Karimi *et al*., 2012). Conservation agriculture along with some water saving technological interventions like alternate raised and sunken bed technique in low lands, system of rice intensification (SRI) technique of rice cultivation and mulching etc. can be adopted to increase crop yield, to reduce evapo-transpiration and water footprints (Kar *et al*., 2014). Crop residue retention help in reducing the water requirement by conserving soil moisture through a reduction in evaporation loss and improvement in the water-holding capacity (Gathala *et al*., 2013). Higher water productivity (33-56%) under conservation agriculture (zero tillage + crop residues) was observed in cereal based cropping system (Jat *et al*., 2020) in the North West Indo-Gangetic Plain of India due to better grain yields with less water usage. Planting of crop on ridges, straw mulching and micro irrigation (sprinklers and drips) can also help in reducing water use, and thereby carbon footprint. Rotational irrigation is often recommended to irrigate a large area with a limited water supply which also ensures more effective use of rainfall.

Diversification of crop rotations

Crop diversification has been considered a key agriculture practice for improving agro-ecosystem productivity and lowering the carbon footprint (Gan *et al*., 2015). Crop diversification help in controlling weeds (Harker *et al*., 2009), suppressing plant diseases (Kutcher *et al*., 2013), and thereby increase production sustainability (Mhango *et al*., 2013). Researchers found that the total emissions per unit of land varied significantly among the various cropping systems. Average GHG emission and the carbon footprint of biomass based cropping system were found maximum in cereal based cropping system (Table 4). Incorporation of pulse crops in the crop rotation helped in reducing the total GHG and carbon footprint.

Table 4: GHG emission and carbon foot print in biomass based crop rotation

Cropping system	Total emission (kg CO_2 eq kg^{-1} yr^{-1})	Carbon foot print (kg CO_2eq kg^{-1} yr^{-1}
Wheat-maize	11800	0.85
Groundnut-wheat-maize	8532	0.76
Mustard-cotton-groundnut-wheat-maize	8324	0.68

Source: Yang *et al*. (2014)

In designing a diverse cropping system, there is need to examine the overall greenhouse gas emissions and the footprint of individual crop. Crops requiring low production inputs and those with a high yield of straw and roots for incorporation into the soil as carbon are keys to reducing the overall footprint of the system. Pathak *et al*. (2011) reported carbon sequestration potential of field crops under various cropping system (Table 5). The carbon build-up rate was maximum under jute-rice-wheat and maize-soybean-wheat cropping system.

Table 5: Potential of carbon sequestration of field crops under various crop rotation

Cropping system	C sequestration potential t C eq ha^{-1}	Reference
Jute-rice-wheat	1.45 – 3.33	Manna *et al*. (2005)
Maize-soybean-wheat	0.43 – 3.82	Hati *et al*. (2007)
Rice-wheat	0.41 – 1.87	Yadav *et al*. (2000)
Soybean-wheat	0.40 – 1.67	Behera *et al*. (2007)

Source: Pathak *et al*. (2011)

Intensifying crop rotations with less summer fallow frequencies

In arid and semiarid regions, the productivity of agroecosystems is often constrained by a low availability of water and nutrients (Rasouli *et al*., 2014). One of the approaches employed to tackle these challenges is using summer fallow where the land is left unplanted for one growing season. During summer fallow, a proportion of the rainfall is conserved in the soil profile (Tanwar *et al*., 2014), which is then available for crops grown the following year (Sun *et al*., 2013). Additionally, summer fallowing encourages the release of N through the N mineralization of soil organic matter (Campbell *et al*., 2008), thus increasing soil N availability and helping to reduce the amount of inorganic N fertilizer used in cropping (Koutika *et al*., 2004). However, a number of studies have shown that the frequency of summer fallow in a crop rotation has a significant impact on the carbon footprint of the rotation (O'Dea *et al*., 2013; Schillinger and Young, 2014). Crop intensification with reduced frequency of summer fallow in a rotation can increase crop production while reducing the carbon footprint. More intensified crop rotation systems with reduced frequency of summer fallow in the rotation can reduce the carbon footprint by as much as 250% (Liu *et al*., 2016). Replacement of summer fallow with a forage or grain legume are more helpful in reducing the carbon footprint in addition to double farming profits compared with the system with a high frequency of summer fallow.

Integrating key cropping practices

Integrated cropping systems coupled with the adoption of best agronomic practices such as early sowing, optimum plant establishment methods (e.g. SRI in rice), use of recommended amount of fertilizer at right time using soil health card, and proper crop sequencing can increase crop productivity without increasing production inputs or GHG emissions. (Kirkegaard *et al*., 2008; Miller *et al*., 2003; Singh *et al*., 2000). The carbon footprint of individual crop species is highly associated with crop biomass and the N concentration of plant parts like leaves, straw, stubbles, and roots. Integration of agronomical practices can significantly improve the net productivity of crops by improving the water and nitrogen use efficiencies. The increased net productivity in integrated cropping systems over monoculture systems is due to the improved diversity of the microbial populations and the function of microbial communities in the soil (Yang *et al*., 2013; Cruz *et al*., 2012). Leguminous-based cropping systems reduce the loss of soil organic carbon and nitrogen as compared to only cereal-based cropping systems (Gan *et al*., 2014). A system that includes leguminous crop in the rotation has the lowest carbon footprint, regardless of the geographical locations (Fig. 3). Many studies across the world demonstrate that use of integrated agronomical practices can increase the system productivity by 15 to 50 %, reduce the carbon emissions associated with the crop inputs by 25 to 50 %, and lower the carbon footprint of cereal crops by 25 to 35 % (Berry *et al*., 2008; Elsgaard *et al*., 2013; Syp *et al*., 2012; Brock *et al*., 2012; Gan *et al*., 2011).

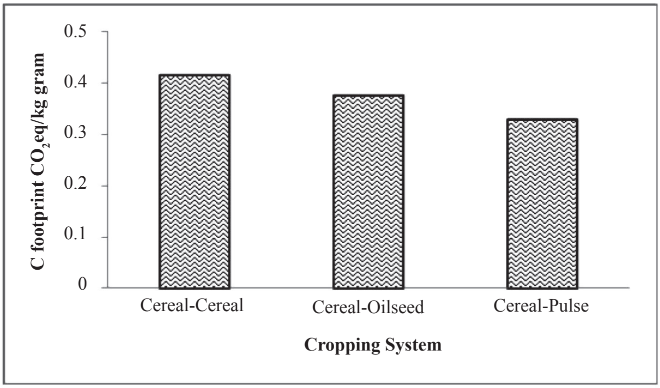

Fig. 3: Soil and crop management practices associated with carbon sequestration

Source: Gan *et al*. (2014)

Enhancing Soil Carbon Sequestration

The Intergovernmental Panel on Climate Change has identified one of the most important options for greenhouse gas mitigation is the sequestration of carbon into soils (IPCC, 2006). Several studies demonstrate that soil carbon sequestration plays a key role in reducing the carbon footprint of crop cultivation, because a per unit farmland GHG emission represents the balance between CO_2-eq emissions and carbon sequestration during the cultivation of crops per year. Modern soil and crop management practices have resulted in loss of SOC. Main agronomic practices for SOC loss are improper tillage operations, minimum crop rotations and residues management, imbalanced soil fertilization, and less use of organic compost or FYM. Hence, suitable crop and land management practices can be used to increase the amount of organic matter in the soil and thereby improve soil carbon sequestration, and mitigate GHG emissions to the atmosphere. About 1400 Pg of SOC is stored in surface soil (1 m depth), while 450 Pg SOC is stored above ground vegetation and dead organic matter. Increase in cropping intensity and reducing the frequency of fallow period in the crop rotation is an effective approach to improve biomass production and it also decreases organic matter decomposition rate and mineralization/oxidation of SOC (Dumanski *et al*., 1998). GHG emissions associated with the crop production inputs can be offset by greater carbon conversion from atmospheric CO_2 into plant biomass and ultimately sequestered into the soil (Sainju *et al*., 2010; Pinheiro *et al*., 2015, Hu *et al*., 2015). Inclusion of intercropping in the crop rotation with reduced tillage coupled with stubble mulching can effectively lower carbon emissions and increase soil carbon sequestration within the small macro-aggregates and micro-aggregates of surface soil (Garcia-Franco *et al*., 2015). Growing legumes as intercrop can substantially reduce the chemical N fertilizers application. Mixed cropping is also an effective approach in the intercropping system to balance the input and output of soil nutrients, suppress weeds and insects, control plant disease, and to increase the overall productivity with limited resources (Hirst 2009). Appropriate land/soil management programs are required to optimize carbon conversion from the atmosphere while minimizing carbon loss in the production of crops. Management of soil health friendly farming systems, minimization of soil and water loss by surface runoff and erosion, adoption of INM and organic amendment are found helpful in CO_2 sequestration (Singh and Lal, 2005). Reported data of C sequestration associated under soil and crop management practices are presented in Table 6.

Table 6: Soil and crop management practices associated with carbon sequestration

Management practice	Carbon sequestration (*MMT C yr^{-1})
Crop rotation and cover crops	5.1 – 15.3
Crop residue management	11 – 67
Fertilizer management	6 – 18
Livestock manure (FYM)	3.6 – 9.0
Supplemental irrigation	1.0 – 3.2
Conservation tillage	17.8 – 35.7
Fallow reduction	1.4 – 2.7
**MMTC: Million metric tons of carbon*	

Source: Follett (2001)

Conclusion

Crop production practices which leads to less carbon emission are more desirable for sustainability and environmental safety from any production system. The transition to low-carbon agriculture requires identification of appropriate systems and management practices based on the farm resources available. Diversification of cropping systems, adoption of leguminous based crop rotation with reduced summer fallow, use of reduced tillage in combination with crop residue retention, improvement of nitrogen use efficiency, and enhancement of carbon sequestration into the soil together enhances agronomic productivity per unit consumption of C-based input. Adopting such holistic approach which decreases losses of crop, soil and water resources are important strategy to reduce the carbon footprint.

References

Banik A., Sen, M. and Sen, S.P. (1993). Methane emission from jute-retting tanks. *Ecological Engineering,* 2:73-79.

Behera, U., Sharma, A. and Pandey, H. (2007). Sustaining productivity of wheat–soybean cropping system through integrated nutrient management practices on the Vertisols of central India. *Plant and Soil,* 297:185–199.

Berry, P.M., Kindred, D.R., Paveley, N.D. (2008). Quantifying the effects of fungicides and disease resistance on greenhouse gas emissions associated with wheat production. *Plant Pathology,* 57:1000–1008.

Brock, P., Madden, P., Schwenke, G., Herridge, D. (2012). Greenhouse gas emissions profile for 1 tonne of wheat produced in Central Zone (East) New South Wales: a life cycle assessment approach. *Crop and Pasture Science,* 63:319–329.

Bumb, Balu L. and Baanante, Carlos A. (1996). *Policies to promote environmentally sustainable fertilizer use and supply to 2020.* 2020 Brief 40, International Food Policy Research Institute, Washington DC

Campbell, C.A., Lafond, G.P., Van den Bygaart A.J., Zentner, R.P., Lemke, R., May, W.E., Holzapfel, C.B. (2011). Effect of crop rotation, fertilizer and tillage management on spring wheat grain yield and N and P content in a thin Black Chernozem: a long-term study. *Canadian Journal of Plant Science,* 91:467–483.

Campbell, C.A., Zentner, R.P., Basnyat, P., DeJong, R., Lemke, R. and Desjardins, R., Reiter, M. (2008). Nitrogen mineralization under summer fallow and continuous wheat in the semi-arid Canadian prairie. *Canadian Journal of Soil Science*, 88:681–696.

Carbon Trust (2007). Carbon Footprint Measurement Methodology, Version 1.1. The Carbon Trust, London

Choudhary, M., Rana, K.S., Bana, R.S., Ghasal, P.C., Choudhary, G.L., Jakhar, P. and Verma, R.K. (2017). Energy budgeting and carbon footprint of pearl millet–mustard cropping system under conventional and conservation agriculture in rainfed semi-arid agro-ecosystem. *Energy*, 141:1052–1058.

Collins, N.E., Kimble, L.J. and Williams, T.H. (1976). Energy requirements for tillage on coastal plains soils. In: Lockeretz W, editor. Agriculture and energy. Academic Press, New York, p.233

Condron, L. M., Tiessen, H., Trasar-Cepada, C., Moir, J. O., and Stewart, J.W.B. (1993). Effects of liming on organic matter decomposition and phosphorous extractability in an acid humid Ranker soil from northwest Spain. *Biology and Fertility of Soils,* 15: 279–284.

Cruz, A.F., Hamel, C., Yang, C., Matsubara, T., Gan, Y., Singh, A.K., Kuwada, K. and Ishii, T. (2012). Phytochemicals to suppress Fusarium head blight in wheat-chickpea rotation. *Phytochemistry*, 78: 72–80.

Dhiman, S. D., Nandal, D. P., and Om, H. (2000). Productivity of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system as affected by its residue management and fertility levels. *Indian Journal of Agronomy,* 45: 1–5.

Dumanski J., Desjardins, R.L., Tarnocai, C., Moreal, C., Gregorich, E.G., Kirkwood V. and Campbell C.A. (1998). Possibilities for future carbon sequestration in canadian agriculture in relation to land use changes. *Journal of Climate Research,* 40(1): 81-103.

Dwivedi, B.S. (2017). Revamping soil testing service: a pre-requisite for effective implementation of Soil Health Card Scheme. *Journal of Indian Society of Soil Science,* 65(S): 62-71.

Dyer, J.A. and Desjardins, R.L. (2003). The impact of farm machinery management on the greenhouse gas emissions from Canadian agriculture. *Journal of Sustainable Agriculture,* 22: 59-74.

Dyer, J.A. and Desjardins, R.L. (2006). Carbon dioxide emissions associated with the manufacturing of tractors and farm machinery in Canada. *Biosystems Engineering,* 93(1): 107-118

Elsgaard, L., Olesen, J.E., Hermansen, J.E., Kristensen, I.T., Børgesen, C.D. (2013). Regional greenhouse gas emissions from cultivation of winter wheat and winter rapeseed for biofuels in Denmark. *Acta Agriculturae Scandinavica, Section B,* 63:219–230.

FE (2014). Mineral fertiliser carbon footprint reference values. Fertilizers Europe, Brussels, Belgium

Follett, R.F. (2001). Soil management concepts and carbon sequestration in cropland soils. *Soil Tillage Research,* 61:77-92.

Forster, P., Ramaswamy, V., Artaxo, P., Bemsten, T., Betts, R., Fahey, D.W., Haywood, J., Lowe, D.C. and Myhre (2007). Changes in atmospheric constituents and in radiative forcing, In: Climate change 2007: The Physical Science Basis Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, pp 129-234.

Gan, Y., Liang, C., Wang, X. and McConkey, B. (2011). Lowering carbon footprint of durum wheat by diversifying cropping systems. *Field Crop Research,* 122:199–206.

Gan, Y., Liang, C., Chai, Q., Lemke, R.L., Campbell, C.A. and Zentner, R.P. (2014). Improving farming practices reduces the carbon footprint of spring wheat production. *Nature Communications,* 5: 5012–5012.

Gan, Y., Hamel, C., O'Donovan, J.T., Cutforth, H., Zentner, R.P., Campbell, C.A., Niu, Y., Poppy and L. (2015). Diversifying crop rotations with pulses enhances system productivity. *Nature Scientific Reports,* 5: 14625.

Garcia-Franco, N., Albaladejo, J., Almagro, M. and Martínez-Mena, M. (2015). Beneficial effects of reduced tillage and green manure on soil aggregation and stabilization of organic carbon in a Mediterranean agroecosystem. *Soil Tillage Research,* 153: 66–75.

Gathala, M.K., Kumar, V., Sharma, P.C., Saharawat, Y.S., Jat, H.S., Singh, M., Kumar, A., Jat, M.L., Humphreys, E., Sharma, D.K. and Sharma, S. (2013). Optimizing intensive cereal-based cropping systems addressing current and future drivers of agricultural change in the northwestern Indo-Gangetic Plains of India. *Agriculture Ecosystem and Environment*, 177: 85–97.

Grant Thornton (2016). Accelerating growth of Indian agriculture: Micro irrigation an efficient solution, Grant Thornton India LLP., New Delhi

Harker, K.N., O'Donovan, J.T., Irvine, R.B., Turkington, T.K., Clayton and G.W. (2009). Integrating cropping systems with cultural techniques augments wild oat (*Avena fatua*) management in barley. *Weed Science,* 57: 326–337.

Hati, K.K., Swarup, A., Dwivedi, A.K. (2007). Changes in soil physical properties and organic carbon status at the topsoil horizon of a Vertisol of central India after 28 years of continuous cropping, fertilization and manuring. *Agriculture, Ecosystem and Environment,* 119: 127–134.

Hirst, K.K. (2009) Mixed Cropping, Agricultural Technique Known as Mixed Cropping. http://archaeology.about.com/od/historyofagriculture/qt/mixed_cropping.html (access date: 3/28/2010)

Hu, F., Chai, Q., Yu, A., Yin, W., Cui, H., Gan, Y. (2015). Less carbon emissions of wheat–maize intercropping under reduced tillage in arid areas. *Agronomy for Sustainable Development,* 35: 701–711.

IPCC (2006). Intergovernmental panel on climate change. 2006 IPCC Guidelines for National Greenhouse Gas Inventories-Vol 4, Agriculture, Forestry and Other Land Use: Geneva 2, Switzerland

IRRI (1986). Annual Report. International Rice Research Institute, Los Banos, Philippines

Jat, H.S., Choudhary, K.M., Nandal, D.P., Yadav, A.K., Poonia, Tanuja, Singh, Yadvinder, Sharma, P.C. and Jat, M.L. (2020). Conservation Agriculture-based Sustainable Intensification of Cereal Systems Leads to Energy Conservation, Higher Productivity and Farm Profitability. *Environmental Management* https://doi.org/10.1007/s00267-020-01273-w

Jenny, H. and Raychaudhuri, S.P. (1960). Effect of climate and cultivation on nitrogen and organic matter resources in Indian soils. Indian Council of Agricultural Research, New Delhi

Kar, G., Singh, R., Kumar, A. and Sikka, A.K. (2014). Farm Level Water Footprints of Crop Production: Concept and Accounting. Bulletin No.-67. Directorate of Water Management, Indian Council of Agricultural Research, Chandrasekharpur, Bhubaneswar, India, p. 56

Karimi Poolad, Qureshi Asad Sarwar, Bahramloo Reza and Molden David (2012). Reducing carbon emissions through improved irrigation and groundwater management: A case study from Iran *Agricultural Water Management,* 108: 52-60.

Kirkegaard, J., Christen, O., Krupinsky, J., Layzell, D. (2008). Break crop benefits in temperate wheat production. *Field Crops Research,* 107: 185– 195.

Koutika, L.S., Ndango, R., Hauser, S. (2004). Nutrient concentrations and NH_4^+−N mineralization under different soil types and fallow forms in southern Cameroon. *Journal of Plant Nutrition and Soil Science,* 167: 591–595.

Kumar, V., Ghosh, B.C., and Bhat, K. (2000). Complementary effect of crop wastes and inorganic fertilizers on yield, nutrient uptake and residual fertility in mustarad (*Brassica juncea*) rice (*Oryza sativa*) cropping sequence. Indian *Journal of Agriculture Science,* 70: 69–72.

Kutcher, H.R., Brandt, S.A., Smith, E.G., Ulrich, D., Malhi, S.S. and Johnston, A.M. (2013). Blackleg disease of canola mitigated by resistant cultivars and four-year crop rotations in western Canada. *Canadian Journal of Plant Pathology,* 35: 209–221.

Ladd, J.N., van Gestel, M., Monrozier, L. J., and Amato, M. (1996). Distribution of organic ^{14}C and ^{15}N in particle-size fractions of soils incubated with ^{14}C, ^{15}N-labelled glucose, NH_4, and legume and wheat straw residues. *Soil Biology and Biochemistry,* 28: 893–905.

Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *Science,* 304: 1623–1627.

Lal R. (2004a). Carbon emission from farm operations. *Environment International*, 30: 981-990.

Liu, Chang, Cutforth, Herb, Chai, Qiang and Gan, Yantai (2016). Farming tactics to reduce the carbon footprint of crop cultivation in semiarid areas, A review. *Agronomy for Sustainability Development,* 36: 69.

Manna, M.C., Swarup, A. and Wajari, R.H. (2005). Long-term effect of fertilizer and manure application on soil organic carbon storage, soil quality and yield sustainability under sub-humid and semi-arid tropical India. *Field Crops Research,* 93: 264–280.

Mhango, W.G., Snapp, S.S. and Phiri, G.Y.K. (2013). Opportunities and constraints to legume diversification for sustainable maize production on smallholder farms in Malawi. *Renewable Agriculture and Food Systems,* 28: 234–244.

Miller, P.R., Gan, Y., McConkey, B.G., McDonald, C.L. (2003). Pulse crops for the northern Great Plains. *Agronomy Journal,* 95: 980–986.

Nelson, P. N., Ladd, J. N., and Oades, J. M. (1996). Decomposition of ^{14}C-labelled plant material in a salt-affected soil. *Soil Biology and Biochemistry,* 28: 433–441.

O'Dea, J.K., Miller, P.R., Jones, C.A. (2013). Greening summer fallow with legume green manures: on-farm assessment in North-Central Montana. *Journal of Soil Water Conservation,* 68: 270–282.

Pathak, H. and Wassmann, R. (2007). Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: I. Generation of technical coefficients. *Agriculture System,* 94: 807-825.

Pathak, H., Byjesh, K., Chakrabarti, B. and Aggarwal, P.K. (2011). Potential and cost of carbon sequestration in Indian agriculture: Estimates from long-term field experiments. *Field Crops Research,* 120: 102–111.

Pinheiro, É.F.M., De Campos, D.V.B., De Carvalho, B.F., Dos Anjos, L.C. and Pereira, M.G. (2015). Tillage systems effects on soil carbon stock and physical fractions of soil organic matter. *Agricultural System,* 132: 35–39.

Rahman, M.A.T.M.T., Aktar, Z., Mondal, M.K. and Ahmed, T. (2012). Environmental friendly agricultural practice in the southwestern coastal zone of Bangladesh to adapt with climate change. *International Journal of Innovative Research Development,* 1(9): 33-44.

Rasouli, S, Whalen, J.K., Madramootoo, C.A. (2014). Review: reducing residual soil nitrogen losses from agroecosystems for surface water protection in Quebec and Ontario, Canada: best management practices, policies and perspectives. *Canadian Journal of Soil Science,* 94: 109–127.

Sainju, U.M., Jabro, J.D. and Caesar-TonThat, T. (2010). Tillage, cropping sequence, and nitrogen fertilization effects on dryland soil carbon dioxide emission and carbon content. *Journal of Environmental Quality,* 39: 935–945.

Schillinger, W.F., Young, D.L. (2014). Best management practices for summer fallow in the World's driest rainfed wheat region. *Soil Science Society of America Journal,* 78: 1707–1715.

Singh, A.K., Roy, M.L. and Ghorai, A.K. (2020). Optimize fertilizer use management through soil health assessment: Saves money and the environment. *International Journal of Current Microbiology and Allied Science,* 9(6): 322-330.

Singh A.K., Behera M.S., Mazumdar S.P. and Kundu D.K. (2019). Soil Carbon Sequestration in Long-Term Fertilization under Jute-Rice-Wheat Agro-Ecosystem. *Communications in Soil Science and Plant Analysis,* 50(6): 739-748.

Singh, A.K., Kumar, Mukesh and Mitra, S. (2018). Carbon footprint and energy use in jute and allied fibre production. *The Indian Journal of Agriculture Science,* 88(8): 1305-11.

Singh, Balram and Lal, Ratan (2005). The potential of soil carbon sequestration through improved management practices in Norway. *Environment, Development and Sustainability,* 7: 161-184.

Singh S., Singh S., Pannu C.J.S. and Singh J. (1999). Energy input and yield relations for wheat in different agro-climatic zones of the Punjab. *Applied Energy,* 63: 287–98.

Singh, Yadvinder, Singh, Bijay and Timsina, J. (2005). Crop Residue Management for Nutrient Cycling and Improving Soil Productivity in Rice-Based Cropping Systems in the Tropics. *Advances in Agronomy,* 85: 269–407.

Soltani, A., Rajabi, M.H., Zeinali, E. and Soltani, E. (2013). Energy inputs and greenhouse gases emissions in wheat production in Gorgan Iran. *Energy,* 50 (50): 54–61.

Sun, M., Gao, Z.Q., Zhao, W.F., Deng, L.F., Deng, Y., Zhao, H.M., Ren, A.X., Li, G., Yang, Z.P. (2013). Effect of Subsoiling in fallow period on soil water storage and grain protein accumulation of dryland wheat and its regulatory effect by nitrogen application. PLoS One 8

Syp, A., Jarosz, Z., Faber, A., Borzecka-Walker, M., Pudełko, R. (2012). Greenhouse gas emissions from winter wheat cultivation for bioethanol production in Poland. *Journal of Food, Agriculture and Environment,* 10: 1169–1172.

Tanwar, S.P.S., Rao, S.S., Regar, P.L., Datt, S., Praveen, K., Jodha, B.S., Santra, P., Kumar, R., Ram, R. (2014). Improving water and land use efficiency of fallow-wheat system in shallow lithic Calciorthid soils of arid region: introduction of bed planting and rainy season sorghum-legume intercropping. *Soil Tillage Research,* 138: 44–55.

Velayutham, M., Pal, D.K., and Bhattacharyya, T. (2000). Organic carbon stock in soils of India. In*:* Global Climatic Change and Tropical Ecosystems (eds. Lal R., Kimble J.M., and Stewart B.A.,). Advances in Soil Science, CRC Press, Boca Raton. pp. 71–95.

Verma, T. S., and Bhagat, R. M. (1992). Impact of rice straw management practices on yield, nitrogen uptake and soil properties in a wheat-rice rotation in northern India. *Fertilizer Research,* 33: 97–106.

Yadav, R.L., Dwivedi, B.S., Prasad, K., Tomar, O.K., Shurpali, N.J. and Pandey, P.S. (2000). Yield trends and changes in soil Organic-C and available NPK in a long-term rice–wheat system under integrated use of manures and fertilisers. *Field Crops Research,* 68: 219–246.

Yang, C., Hamel, C., Gan, Y., Vujanovic, V. (2013). Pyrosequencing reveals how pulses influence rhizobacterial communities with feedback on wheat growth in the semiarid prairie. *Plant Soil*, 367: 493–505.

Yang, X., Gao, W., Zhang, M., Chen, Y. and Sui, P. (2014). Reducing agricultural carbon footprint through diversified crop rotation systems in the North China Plain. *Journal of Clean Production,* 76:131–139.

CONSERVATION AGRICULTURE AND CLIMATE CHANGE

IMPACTS AND ADAPTATIONS

Conventional tillage and burning crop residues has degraded the soil resource base and intensified soil degradation with concomitant decrease in crop production capacity. The emerging issue of global warming coupled with greenhouse gases emissions has further aggravated the scenario. Conservation agriculture (CA) helps in reducing many negative effects of conventional agriculture such as soil erosion, soil organic matter (SOM) decline, water loss, soil physical degradation, and fuel use. CA helps to improve biodiversity in the natural and agro-ecosystems. Complemented by other good agricultural practices (GAPs) including the use of quality seeds, integrated pest, nutrient and water management etc., CA provides a base for sustainable intensification of the agricultural production system. Moreover, the yield levels in CA systems are comparable and even higher than traditional intensive tillage systems with substantially less production costs.

The conservation agriculture (CA) practiced over an estimated 100 M ha area worldwide and across a variety of climatic, soil and geographic zones, has proved to be energy and input efficient, besides addressing the emerging environment and soil health problems. The CA technologies involving no- or minimum tillage with direct seeding and bed planting, residue management (mainly residue retention) and crop diversification have potential for improving productivity and soil quality, mainly by soil organic matter (SOM) build-up.

This bring many possible benefits including reduced water and energy use(fossil fuels and electricity), reduced greenhouse gas (GHG) emissions, soilerosion and degradation of the natural resource base, increased yields and farm incomes, and reduced labour shortages.

This book entitled "Conservation Agriculture and Climate Change: Impacts and Adaptations" will provide comprehensive understanding of the subject with topics related to climate change mitigation strategies, approaches and impact of conservation agriculture on natural resource management

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